Spat are only weakly attracted to either *T. funebralis* or older *C. adunca*; this attraction is clearly present in older individuals.

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Studies on the Commensal Limpet *Acmaea asmi* in Relation to its Host, *Tegula funebralis*

BY

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(11 Text figures; 2 Tables)

Acmaea asmi (Middendorff, 1849) is a stenotopic limpet which inhabits the rocky intertidal, and lives almost exclusively on *Tegula funebralis* (A. Adams, 1854). By studying distribution in relationship to horizontal and vertical position in the intertidal and by considering distribution in relationship to food and substrate preferences, we hoped to establish a clearer understanding of the adult commensal relationship between *A. asmi* and *T. funebralis*. The following work is a continuation and refinement of studies carried out by Frederick H. Test in 1945, and Ruth Radford in 1959.

DISTRIBUTION

During April and May, 1963, distribution of *Acmaea asmi* was studied along Mussel Point on Monterey Bay, California. Every *A. asmi* noted along five transects by W. Wara & B. Wright (1964, see Figures 1 - 5) was collected with its host and both organisms were measured. Notation of horizontal and vertical position was made.

Since the five transects varied both in length and in slope, horizontal distribution in terms of absolute distance from shore is not particularly significant. However, in all five transects populations were concentrated in the middle areas, the regions affected neither by shore line wave action nor the wave battering of the outer intertidal. 6 186

Furthermore, observations at high tide (Wara & Wright, 1964) revealed a qualitative difference in wave action between the transects and showed that the number of *Acmaea asmi* was generally inversely proportional to the wave battering received by the area. Qualitatively, Area B had very heavy wave action and no *A. asmi* were found; Area A received a heavy battering and the density of *A. asmi* was low. As the wave action decreased from

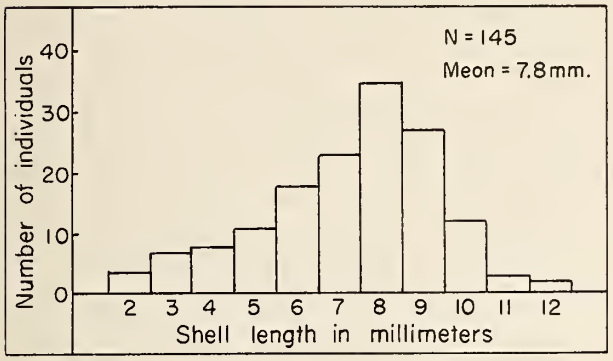

Figure 1: Size frequency of *Acmaea asmi* in the rocky intertidal.

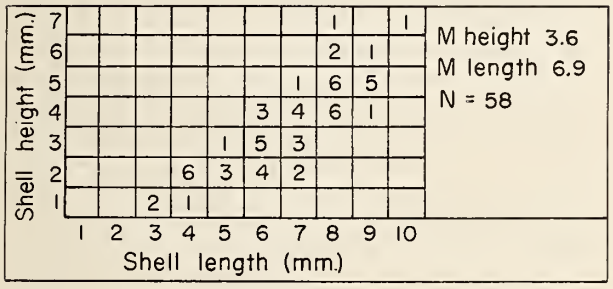

Figure 2: *Acmaea asmi* shell length in relation to position in the intertidal zone.

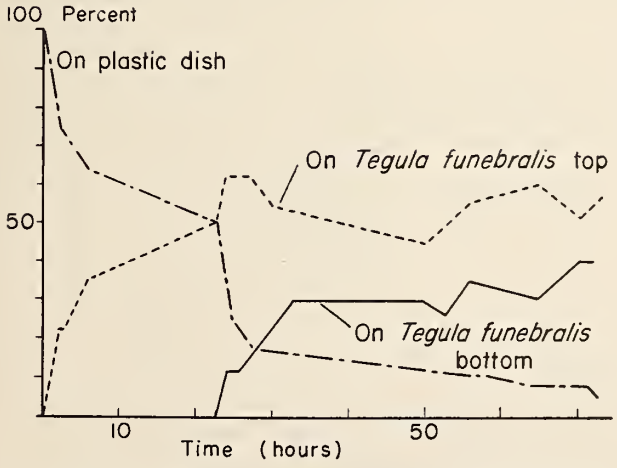

Figure 3: 40 *Acmaea asmi* placed in sea water at 15° C with shell top fragments of *Tegula funebralis*. Later, fragments of shell bottoms were introduced.

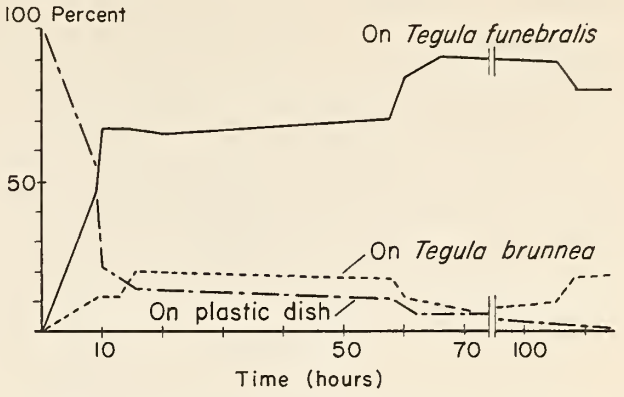

Figure 4: 35 *Acmaea asmi* in sea water at 15° C with living *Tegula funebralis* and *T. brunnea*.

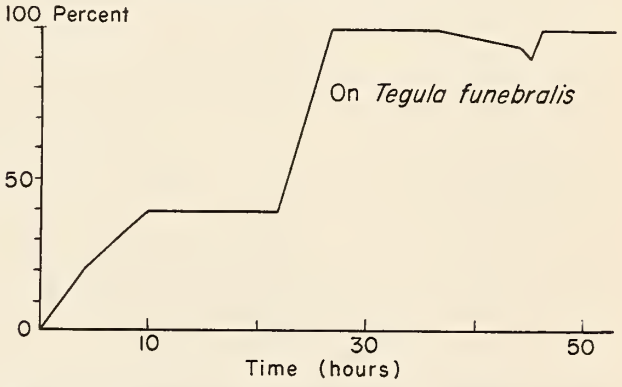

Figure 5: 20 *Acmaea asmi* in sea water of 15° C on *Tegula brunnea* shells either empty or inhabited by *Pagurus* spp., in plastic dishes, with living *Tegula funebralis*.

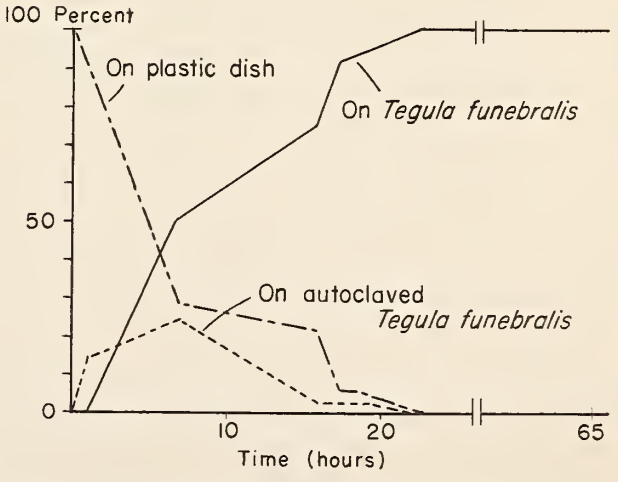

Figure 6: 36 *Acmaea asmi* with autoclaved *Tegula funebralis* shells in sea water of 15° C. An hour later living *Tegula funebralis* were introduced.

areas C to E, the density of *A. asmi* increased more or less proportionately.

Data concerning vertical distribution are shown in Table I; *Acmaca asmi* ranged from 0-6 feet above mean low water with greatest population density at 2-4 feet.

A size frequency histogram of *Acmaea asmi* appears in Figure 1. The anterior-posterior length of the shell taken at the margin of the aperture was measured. Shells under 2 mm in length were observed but could not be identified

Table 1

	Height in the intertidal		
	0-2 ft.	2-4 ft.	4-6 ft.
Range: no. *A. asmi* per sq. meter	0-8	0-15	0-2
Mean no. *A. asmi* per sq. meter	0.33	1.51	0.6
Range: % *T. funebralis* with *A. asmi* per sq. meter	0-2 %	0-20%	0-8%
Mean % *T. funebralis* with *A. asmi* per sq. meter	0.12%	0.35%	0.35%

Table 1: *Acmaea asmi* distribution in relation to height in the intertidal region.

with certainty, because *A. asmi* resembles other species of *Acmaea* at this size. Sixty shells were measured from base to apex in the middle of the shell; the results, plotted against shell length, appear in Figure 2.

There seemed to be no consistent relationship between *Acmaea asmi* shell size and either vertical or horizontal position. In all vertical positions in areas C through E, mean shell length varied between 7.1 and 7.5 mm and ranged from 4 to 10 mm. In area A, where wave action is greatest, no *A. asmi* measuring less than 8 mm were found, and mean size was 8.7 mm.

The distribution of *Acmaea asmi* on its host was considered next. Numerous *Tegula funebralis* examined showed radulation of the lower part of the shell, while little or none occurred on the shell apex. In the field we noted that *A. asmi* inhabits the lower whorls of the *T. funebralis* shell almost exclusively; only four were observed on the shell apex. F. H. Test (1945) reported he had never seen them on the apex. *Acmaea asmi* measuring 2 mm or less long were generally located on the flattened base of the shell close to the aperture, a position better protected from dessication, direct sunlight, predation, and wind and wave action.

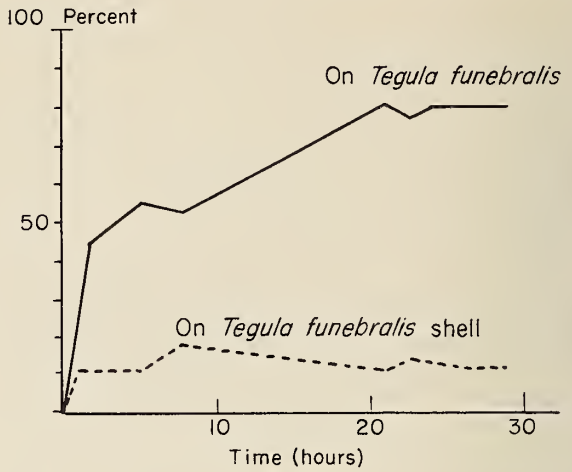

Figure 7: 36 *Acmaea asmi* in sea water of 15° C with (living) *Tegula funebralis* and *T. funebralis* shells from which the animal was removed; the aperture was plugged with plasticene and plaster of paris.

The algal growth on the *Tegula funebralis* shell is relatively uniform; the main organism is a microscopic filamentous green alga tentatively identified as *Gongrosira incrustans* (De Wildemann) Ktzg. (see Schmidle, 1901). An apparently identical alga encrusts the shells of *Acanthina spirata* and *Tegula brunnea*. We observed *Acmaea asmi* feeding on the shells of these animals. Only twice was *A. asmi* seen in the field on *T. funebralis* shells, inhabited by *Pagurus* spp. The pattern that results from radulation is fan-shaped and is produced by the animal feeding from side to side and in a forward direction.

In successive tests, *Acmaea asmi* was placed in varying situations (see Figures 3,4,5,6, and 7). Shells with intact

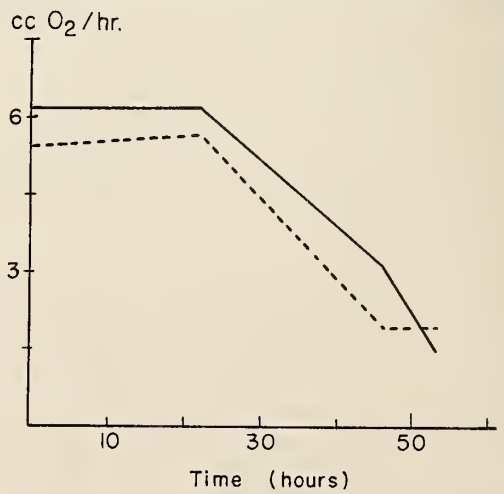

Figure 8: Net O_2 produced by algae after removal of *Acmaea asmi*.

algae but deprived of snails hold a very slight attraction for *A. asmi* in the presence of living *Tegula funebralis* or *T. brunnea*. In an aquarium containing both species of snails, as many as 20% of the *A. asmi* population were found feeding on *T. brunnea,* contrary to the findings of Radford (1959). *Acmaea asmi* is found only rarely on *T. brunnea* in the field. However, *T. brunnea* is found only in the lower intertidal and is exposed to heavier wave action.

From these experiments we conclude that *Acmaea asmi* is attracted to living *Tegula funebralis* or *Tegula brunnea* due, not only to the source of food on the shell but also to some property of the living snails, possibly a secreted or excreted substance or substances.

Attempts were made to determine the feeding rate and food preferences of *Acmaea asmi* and the rate of recovery of the algal crop on *Tegula funebralis*. Respiration and photosynthesis as measured by the Winkler method were used as an index of grazing.

Tegula funebralis were removed from their shells with a dissecting needle. The shell was filled with plaster of Paris coated with paraffin to prevent exchange of gas of any remaining tissues. The shells were placed in a 150 cc jar, in a water bath at 14.5-16° C, and exposed to an incandescent light source kept at constant intensity of 250 foot-candles.

Acmaea asmi starved for 52 hours to insure maximum feeding were placed on the shells. A ratio of one *A. asmi* to one *Tegula funebralis* shell was used since this is the normal condition in the field.

After the animals had grazed on the shells, the shells were placed for three hours in the dark. Consumption of oxygen decreased, indicating less algae present, presumably due to removal by *Acmaea asmi*. These results indicate that one group of three starved *A. asmi* may eat from 2.7 to 7.0% of the algae on three *Tegula funebralis* shells per hour. (see Table II).

Six of the above 12 shells (see Figure 8) were exposed to light and algal recovery was measured. The results indicated a further decrease of photosynthesis after *Acmaea asmi* had been removed.

Finally, we attempted to determine rate of transfer by *Acmaea asmi* under laboratory conditions. Disagreement exists in the literature on the frequency with which *A. asmi* changes hosts. F. H. Test (1945) noted that *A. asmi* generally spend less than 24 hours on one host. Ruth Radford (1959) observed several *A. asmi* remaining over a week on one host.

Experimental results favored Test's statement. In Group A, 45 *Acmaea asmi* on 35 *Tegula funebralis* were marked with nail polish in a dot-dash code. They were placed in a 12 inch diameter bowl, provided with running

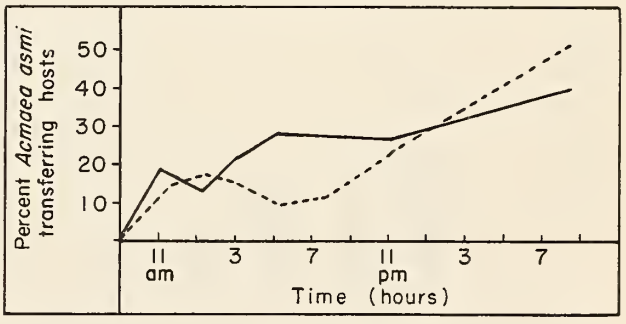

Figure 9: Transfer rate of *Acmaea asmi* from one *Tegula funebralis* to another, plotted in two hour periods in normal diurnal change (solid line) and in constant darkness (dashed line).

Table 2

Oxygen consumption and evolution by *Acmaea asmi* and algae. Values for groups of 3 *Tegula funebralis* shells, with and without 3 *Acmaea asmi.*

A. asmi non-feeding O_2 intake	Shells in dark	Shells in light	Shells with *A. asmi* in light	Shells in dark w/o *A. asmi*	% algæ eaten/hr
—0.102cc 0_2/g/hr	—0.0375	+0.084	+0.0165	—0.0345	2.7
	—0.042	+0.114	+0.027	—0.036	4.7
	—0.0465	+0.106	+0.009	—0.0405	4.3
	—0.036	+0.085	+0.010	—0.0285	7.0

Table 2: Oxygen consumption and evolution of *Acmaea asmi* and algae to obtain % of algae eaten and feeding rate of *Acmaea asmi* (cc/l/hr). Figures represent 4 groups, each with 3 *Acmaea asmi* on 3 *Tegula funebralis* shells.

sea-water and subjected to normal light fluctuations. After a twelve hour adjustment period the *A. asmi* were followed individually and their positions recorded every two hours. A second group with 45 *A. asmi* on 31 *T. funebralis,* similarly marked, was run in the dark. The results are shown in Figure 9. Although conditions were crowded, *T. funebralis* in the field is closely clustered.

The *Acmaea asmi* were separated arbitrarily into three size classes and rate of transfer within each class was plotted (see Figure 10). The small and the large transferred less frequently than the medium sized animals.

Figure 11 illustrates the results of three transfer experiments, all run from 6:00 PM to 8:00 AM. Experiments B,C, and D were run in a tank with circulating water, one *Acmaea asmi* per *Tegula funebralis* in the experimental group and an overall ratio of approximately one *A. asmi* to two *T. funebralis.* These tanks were not checked hourly, and it was only noted whether the animals were on their original host after 14 hours.

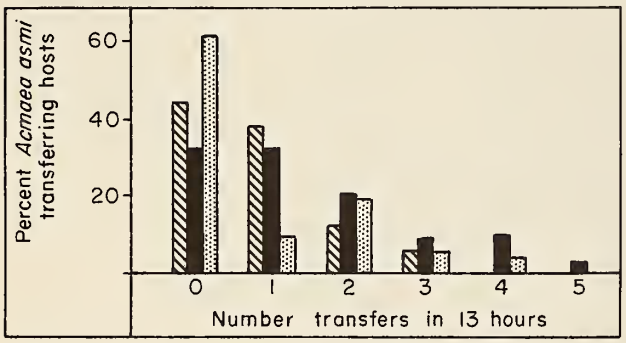

Figure 10: Percent of *Acmaea asmi* (in each size group) transferring in 13 hours in relation to shell length. Dashed line indicates small *Acmaea asmi* (3 - 6 mm); solid line indicates medium size shells (7 - 8 mm); dotted line indicates large size shells (9 - 11 mm).

SUMMARY

Acmaea asmi is distributed in the rocky intertidal at Mussel Point between the vertical height of 0-6 feet (with maximum density from 2-4 feet and from 0-52 meters from the higher high water mark. The animal lives on the shell of *Tegula funebralis* and seems to be attracted not only by microscopic algae as a food source, but also by some property of living *T. funebralis.* Experiments were carried out to determine preference of *A. asmi* for various shell substrates, in addition to investigating the transfer rate. The respiration of the algal crop of *T. funebralis* and of *A. asmi* was measured to find an index of feeding rate.

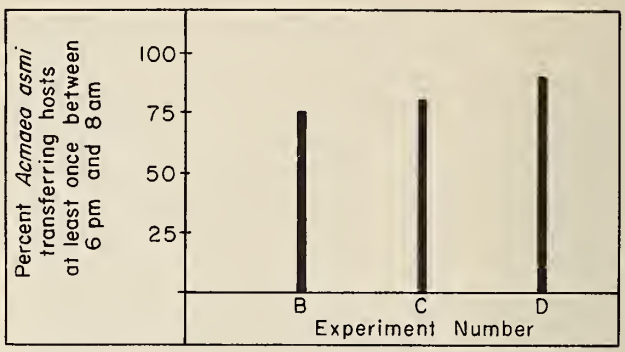

Figure 11: Percent of *Acmaea asmi* transferring from one host to another at least once in the period between 6 p.m. and 8 a.m.

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